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BIOTECHNOLOGY FOR AGRICULTURE: FEDERAL RESEARCH IN PLANT SCIENCES

Dr. Gerald G. Still
Director, Plant Gene Expression Center, USDA, ARS

I am very pleased to have this opportunity to share my thinking with you on this auspicious occasion.

As we know, nearly all of our food comes from only 12 to 15 crop plants; about 90 percent of the caloric intake of the human population is from only 5 cereal crops, 3 tuber crops, 2 sugar crops, and several legumes. Cereal crops alone account for about 70 percent of our food, with wheat and rice, by far, the most important food cereals. These 2-5 cereal crops literally stand between mankind and starvation. And, as important as these 12 to 15 major crops are to our world's economic stability and to the world's political stability, society and its institutions cannot yet completely insure increasing the productivity and quality of these basic human staples.

We have come far, but there is more to be done. You who are plant breeders, pathologists, and agronomists, and your colleagues around the world, have every right to be proud of the job that has been done. With the tools available, it has been a magnificent job. Germplasm has been selected, manipulated, kneaded into an agronomic system that allows farmers to recover an ever-increasing percentage of the potential yield residing in our crop plants. Through genetics and breeding, high-yielding varieties have been released. They possess the myriad traits required in the field. The crop culture and management system seeks to optimize water in relation to nitrogen and other nutrients, while constantly striving to reduce soil erosion and environmental pollution. Through the use of an increasing arsenal of plant protection techniques, this yield potential is protected by removing the deleterious vectors of weeds, insects, and pathogens.

Now, the challenge before us is this: Where do we go from here to meet the minimum needs to ensure increased productivity and the quality of the 12 to 15 crops basic to human survival? Where are those new tools that will produce the quantum leaps that the introduction of nitrogen fertilizer did? How do we look more critically and select more carefully in the important areas of product quality and the numerous characteristics that make the harvestable products useful to man and his commerce? Are there opportunities to develop an agricultural product whose final use is not a stomach, but rather an industrial feed stock?

Agriculture is on the verge of a new era---spawned from enormous investments in physical science from 1957, through the 1960's and into the early 1970's, in what has become known as the "post-Sputnik Physical Science Revolution." As a result of this investment, we are now on the edge of a "Biological Revolution" which will touch all human endeavors and impact the human condition. The scope is enormous--ranging from plant and animal agriculture to human medicine. Already society is responding to the moral and technological impact of the application of the products of the emerging "Biological Revolution." The press has dubbed the first phase of this revolution the "Genetic Engineering" or "Biotechnology" revolution. What is biotechnology? It is the application of physical and biological sciences to provide the knowledge and the ability to manipulate living things through their informational molecules. It is knowledge of the very molecules that make us and the living things about us what they are, and how to regulate these molecules. The nucleic acids, proteins, carbohydrates, and lipids all translate information to various levels of the biological system--subcellular, cellular, organic, whole body, and even community. The behavior of insects is the result of informational lipids whose three-dimensional structures are discrete and specific to the organism and its behavior---karomones and pheromones. Mammals respond in careful orchestration to the progress of life through a multiplicity of interactions of proteins that provide discrete information and function. The plant world, as with all biology, responds in concert to exogenous and endogenous cues through informational molecules from nucleic acids through yet-to-be-determined micro and macro molecules. The new frontiers for agriculture will be the application of informational molecules for bioregulation of field crops and livestock. What is agriculture other than regulating and optimizing the biological system for food, fiber, and feedstock? Agriculture is the application of biological and physical science for our survival and for the profit of those farmers who provide this service for society. The future of agriculture resides in our ability to optimize the use of the informational molecules in agricultural crop plants.

Industry has been a forerunner in this field. Whether it be through plant nutrition or regulation by selective herbicides, plant growth regulators, or biological control materials, it is the application of specific molecular architecture that elicits a specific biological response. These responses are useful in the overall agricultural scheme--whether it be crop production or product protection at the pre- or post-harvest phases of the process.

Farmers have always carried all the risks of weather and of plant disease, weeds, and insect pests. Some of these burdens have been eased. Farmers currently can exert some control by using agrochemicals. The advantage to farmers could be much greater if they had at their disposal an arsenal of exogenous chemical cues that will give the producers and processors alternatives in producing and preparing the agricultural product for commerce.

Why not develop technology so farmers could control the timing of the termination of the vegetative phase of growth and the initiation of the reproductive growth? Why not develop technology to manage the translocation of nutrients in concert with weather and flowering? Why not manage senescence? -- If moisture and weather conditions were favorable, maintaining vegetative or reproductive metabolism one or two weeks in relation to the individual crop year could have profound effects on yield and quality. Why not provide the technology to allow control of seed dormancy? Why not provide a technology that may regulate post-harvest metabolism in order to preserve or create greater quality of the agricultural product for commerce? Each of these proposals comes under the purview of biotechnology for agriculture.

We are also on the threshhold of a new era for agriculture which I believe will have as great an impact as the milestones that I have described earlier. Biotechnology is in its infancy. The pursuit of understanding of informational molecules and how they interact at the molecular, cellular, tissue, organ, and whole system level is a yet-to-be-explored frontier. This is the future of agribusiness, the chemical industry, and agriculture.

In recent years biotechnology has caught the imagination of the press and the public. The expectations for results have been enormous, while our experience is small. The dreams of entrepreneurs have swelled beyond the realities of the science and markets. There is no question that the future for the application and commercialization of informational molecules has an enormous potential. The reality is that the timelines have been unrealistic. The anticipated application of the technology has outstripped the fundamental laboratory's capability of providing the foundation from which the technology will evolve. Our dreams for the application of informational molecules that will orchestrate the biological process for commerce are valid. However, the investment of human and capital resources to understand the intricacies of these codes---the interrelationships between the words, sentences, and paragraphs---have yet to be worked out.

In order to convert these dreams into reality, I see ahead a four-part imperative: We must educate, investigate, automate, and facilitate those dreams through an enlightened public and private policy. How well we succeed in each of these broad areas---even more than specific achievements in the informational molecule field---will directly affect our economic vitality, national security, personal happiness and well-being, far into the next century.

The connection between informational molecules and the first imperative--education--is obvious. The task of education expands far beyond training Ph.D. students and must impact upon the educational preparation of the biological and physical scientists addressing these fields---from the most fundamental to the most applied. This is particularly important when addressing the social policy issue of regulation of informational molecules in science, commerce, and in the environment.

An educated workforce makes possible the second imperative: To investigate---to discover and advance the technology that has been our country's strongest competitive advantage. Economists estimate that during the past two decades, technological advances have contributed almost 40 percent of the increase of our gross national product, and we have not yet reached the limits of such gains. The full promise of advanced technology cannot be realized, however, without a continuing commitment to investigate---including the commitment to basic research upon which fundamental breakthroughs so often depend. Direct economic pay-offs of fundamental research are not always obvious, and are usually long-term. Yet, excellence in basic research is essential, not only for competitive advantage in the coming decade, but also for continuing strength in the next century.

Technological superiority, no matter how substantial, can never be taken for granted. The application of new technology, almost by definition, diminishes its value in competitiveness. The diffusion of technology can be stemmed partially and temporarily by enforcement and strengthening of the laws regarding intellectual property, but the only long-term assurance of technological superiority is to stay on the leading edge.

Our third challenge--automation--is imperative because nowhere is there a greater need for application of the new technologies of information automation than in the field of biotechnology. In the words of John Nesbitt, "We are drowning in information and starving for knowledge." The most modern automated informational systems must be brought to bear on the biotechnology for agriculture. The myriad traits, characters, and quality requirements that the plant breeder and geneticist are faced with are all biologically managed by informational molecules. If, in fact, technological superiority is to be achieved, automated information systems must be created, applied, and must evolve simultaneously with the growth and application of biotechnology. Genetics is a science of large numbers of traits, characters, and individuals. Tools must evolve that will fit the hands of plant breeders and geneticists to allow them to apply biotechnology to their problems. In great part, information automation will be that tool.

The fourth challenge before us is to facilitate these important and positive initiatives into a coherent public and private policy---one that recognizes the link between an educated workforce and productive R&D; between R&D and capital investment; between both of these and tax policy; between tax policy and trade policy; between trade policy and fiscal and monetary policy; and between all of these policies and competitive positions and global markets.

The task of development of biotechnology for agriculture is daunting in its scope, but it is vital to our future. At stake is not only international prestige, but survival--not only our standard of living, but also our national security and the quality of our life. The impact of a healthy and productive world agriculture demands the most single-minded focus, the most zealous efforts, and the finest of dedicated commitment. But, it is not beyond our reach. If we act quickly, decisively, and effectively, we--the world community--will develop biotechnology for agriculture--design agricultural products for value-added markets, increase efficiencies in production and processing, and minimize the degradation of our globe's non-renewable resources. And, we will not forget that 2 to 5 cereal crops stand between man and starvation, and that we must be grateful stewards of the 12 to 15 major crops that support our way of life.

Indeed, the issue before us is the future of agriculture. Through informational molecules, let us lay the foundation with today's experiences to realize tomorrow's expectations.